"Design of a Press for Oil Extraction from Moringa Seeds for Haiti"

by

Alessandra Maria Sabelli

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Submitted to the Department of Mechanical Engineering on January 26, 2003, in partial fulfillment of the requirement for the degree of Bachelor of Science recommended by the Mechanical Engineering

Abstract

The project here presented focuses on the development of a harvesting tool for Haiti, a developing country, for the extraction of oil from the seeds of the moringa trees. Moringas have an extraordinarily nutritional potential that can help, at least short-term, to solve problems associated with poor nutrition in the area. Furthermore, moringas naturally prosper in Haiti, making it an accessible and inexpensive resource. A first design is presented in this thesis along with the relevant experimentation and results, and progressive development of possible designs. One of the major concerns regarding the extraction process has been the reabsorption of the oil due to the elastic property of the seeds. This factor is important because a significant percentage of the oil extracted can potentially be reabsorbed, consequently limiting the efficiency of the extraction process. I consequently selected a continuous system that could better ensure a constant pressure, which seems desirable. Moreover, inevitably the design is a compromise between efficiency and cost. Therefore, it was necessary to select a design that could be cheaply produced, limiting also the necessity to produce the whole design from scratch.
The final design consists of a meat grinder that ends with a cage shaped as section of a cone, the whole being powered by human pedaling. Fresh seeds are inserted in a cone-shaped feeder, while the cake flows out the smaller end of the cage and oil is collected in a container.
This project represents a first step into the development of an extraction tool that maximizes the extraction of oil from moringa seeds, and consequently the consumption of the seeds themselves, not exploited so far.

Thesis Supervisor: David Gordon Wilson
Title: Professor Emeritus, Department of Mechanical Engineering

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Acknowledgments

First of all, I would like to thank my supervisor Professor Dave Wilson for his indispensable guidance in this project and Carl Bielenberg for making available to me his experience, knowledge and equipment. I would like to thank Toby Bashaw for his help in solving technical problem with the batch press. Sanford Holst kindly provided me with his book on moringa that was a great resource and I will give it to Amy Smith to make it available for other MIT students to consult. Rodney Purdue supplied the moringa seeds for experimenting.

I would like to thank my father, Jose Miguel Sabelli, for his encouragement.

List of Pictures

Chapter 1

Introduction – Background research

1.1 Why Moringa - Properties of Moringa

The moringa tree has been used for centuries both for its nutritional (refer to table), anti-inflammatory and medical properties. It was known to the Romans, and today moringa is consumed in areas where it naturally prospers: Haiti, Senegal and India. The fact that moringa trees easily grow in dry climates and bloom a few times a year yielding a high volume of seeds, flowers and leaves makes this type of tree an invaluable source of food and energy.

Table 1

Nutritional Value Chart

Per 100 grams of edible portion:	Pods	Leaves	Leaf Powder
Water (%)	86.9	75.0	7.5
Calories	26	92	205
Protein (g)	2.5	6.7	27.1
Fat (g)	0.1	1.7	2.3
Carbohydrate (g)	3.7	13.4	38.2
Fiber (g)	4.8	0.9	19.2
Minerals (g)	2.0	2.3	-
Ca (mg)	30	440	2003
Mg (mg)	24	24	368
P (mg)	110	70	204
K (mg)	259	259	1324
Cu (mg)	3.1	1.1	0.57
Fe (mg)	5.3	7.0	28.2
S (g)	137	137	870
Oxalic acid (mg)	*10*	*101*	*1.6*
Vitamin A – Beta carotene (mg)	0.11	6.8	16.3
Vitamin B – choline (mg)	423	423	-
Vitamin B_1 – thiamin (mg)	0.05	0.21	2.64
Vitamin B_2 – riboflavin (mg)	0.07	0.05	20.5
Vitamin B_3 – nicotinic acid (mg)	0.2	0.8	8.2
Vitamin C – ascorbic acid (mg)	120	220	17.3
Vitamin E – tocopherol acetate	-	-	113
Arginine (g/16g N)	3.6	6.0	1.33%
Histidine (g/16g N)	1.1	2.1	0.61%
Lysine (g/16g N)	1.5	4.3	1.32%
Tryptophan (g/16g N)	0.8	1.9	0.43%
Phenylanaline (g/16g N)	4.3	6.4	1.39%
Methionine (g/16g N)	1.4	2.0	0.35%
Threonine (g/16g N)	3.9	4.9	1.19%
Leucine (g/16g N)	6.5	9.3	1.95%
Isoleucine (g/16g N)	4.4	6.3	0.83%
Valine (g/16g N)	5.4	7.1	1.06%

Table 1: Nutritional Value Chart of Moringa.
Nutritional values of pods, leaves and leaf powder.

Many NGOs dedicated at helping relieve hunger in poor areas of the world, such as

ECHO (Educational Concerns for Hunger Organization), promote moringa use among communities affected by malnutrition, with extraordinary results. It is quite unclear why, despite its properties, moringa's popularity is limited. Even in Haiti the tree is often disregarded. The purpose of this and similar projects at MIT is to promote the consumption of the tree by developing technology specifically targeted to Haitian needs. Haiti is a small island that is highly dependent on outside resources, which are very expensive for the population, and therefore out of reach for many. Moringa trees can help Haitians to become more independent and more skilled by introducing technology appropriately developed for their use.

Extraction of moringa oil, also known as Ben oil, is commonly done by boiling [2]; however, the minimal quantity of oil extracted combined with the excessive quantities of water wasted in the process makes this method undesirable. Boiling the seeds also diminishes the nutritional value of the oil because it forms an emulsion with the water that is subsequently thrown away. The seeds, from which the oil is extracted, have a bitter earthy taste while the oil has a buttery sweet taste, making the oil a more pleasant product to use in food preparation.

1.2 The Value of Appropriate Technology

Appropriate technology aims at developing forms of sustainable living. It seeks the development of technology to improve human living conditions by fostering knowledge. Its main goal is to create an affordable technology that can enable underdeveloped countries to use and create technology independent of outside resources for repair and maintenance, while teaching them principles of engineering. This transferable technology is aimed at helping Third World craftspeople, farmers and other villagers to invent, create, and contribute to the technological process of their area. Moreover, it is necessary to help villagers to identify their needs and assess their resources; in turn villagers create knowledge and transfer positive energy to make other fellows become independent.

With this definition in mind, I proceeded at creating a harvesting tool, a press targeted specifically at enhancing the oil extraction from moringa seeds, which would motivate people in Haiti to value the tree as a resource for food and energy.

1.3 Oil Extraction – processes

Olive oil is one of the most popular oils among the vegetable ones and its extraction is an ancient practice. The Romans widely consumed this oil and, as a consequence, they developed advanced extraction technology, which is still in use today. Other types of oil, such as that extracted from seeds, undergo similar processing. The basic stages of oil production are: steaming, crushing, malaxation (mixing), and separation of oil from paste [3] [4] [5].

Steaming is performed to soften hard-shelled seeds or fruits, such as those of palms; in some instances it is used to sterilize. Crushing and malaxation are necessary steps to free the oil trapped in drops within the body of the seeds/olives. Separation is performed in combination with crushing/malaxation, although for moringa crushing and malaxation are counterproductive because its seeds reabsorb oil more easily when mashed. Various types of separation have been developed, the most popular being: pressing, centrifuging, selective filtration and boiling. Generally pressing is combined with either centrifuging or selective filtration, while boiling has become a less and less popular method. Centrifuging and selective filtration use the difference in density and viscosity to separate oil from mash. In fact, selective filtration uses a series of metal plates that are cyclically immersed in a mix of oil and paste. The viscosity of the oil causes drops of oil to stick to the plates; the plates are taken out so that the oil can fall, under force of gravity, into a container. Centrifuging exploits the difference in densities of oil and paste to separate them, as described by Stoke's Law. The biggest disadvantage of centrifuging compared to selective filtration is the high expense of energy to spin the centrifuge at high speed, which it makes centrifuging undesirable for this project; on the other hand, energy consumption of selective filtration depends on the surface area of the plates and the velocity of immersion, which is much lower.

1.4 Oil Extruders in Appropriate Technology

According to Casten and Snyder (1985) [6], lever and screw presses are the most popular systems used for village production of oil. In a rural village, industrial machines for extracting oil are not available, and generally production is exclusively done using human power, because in many cases access to electricity is limited.

Sometimes pressing is preceded by boiling or steaming to soften the seeds or olives before pressing. Screw presses are generally preferred to lever ones because the pressure is more easily calibrated and it can be easily applied through animal power. When a lever is used, a sack full of soil is often hung at one end of the lever to apply a torque. The lifting of the heavy sack many times a day makes the lever press less favored compared to the screw press. The simplicity of the concepts under which the two methods work, in principle and application, make their use more effective and appreciated. Appreciation of the principles of a machine is important to guarantee the use of that machine for people to develop skills and improvements that would yield a more effective production.

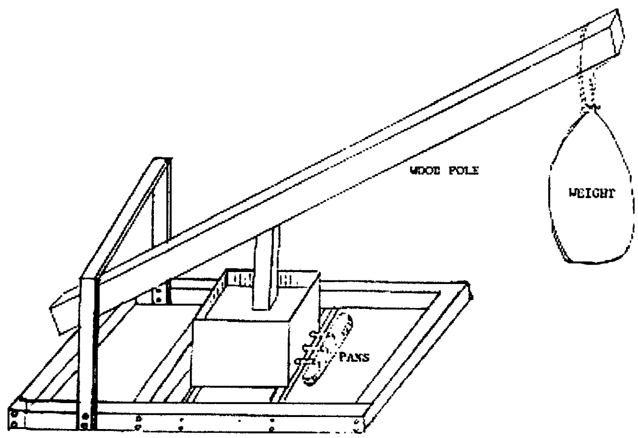


Figure 1: Lever and Box Press.

Source: see Reference [6]

Chapter 2

Experimental Investigation

2.1 Purpose of Investigation

The purpose of the investigation is to establish what properties and methods most influence and affect rural production of oil. Consequently, after a discussion with Carl Bielenberg [7], an engineer who has worked effectively for third-world rural developments, I focused on verifying whether a slowly increasing pressure would effect the extraction of its oil more efficiently than applying a constantly high pressure. I found that no significant difference depended on the manner of application of pressure. The pressure profile therefore is not a relevant factor in obtaining a more productive extraction. Many sources confirmed that the content of oil of moringa seeds is approximately 40% by weight (oil/seeds). Although I expected to be able to extract roughly 10-15% by weight of oil in a one step extraction process [8], I only managed to extract around 6% by weight.

The small percentage of oil that I extracted depends on various factors: the type of process, cage design, type of seeds and mix of different seeds. Other experimentations have shown that with other types of presses, such as a spindle press commonly used in wine making, the highest yielding of oil from Moringa seeds was 13% after optimizing the mix of seeds and the design of a cage [8]. However, moringa oil, known also as Ben oil, is commercially produced in India, by companies like Moringa Exports. While not getting an answer about the methods they use to produce oil, it is likely that they employ extraction processes more common in commercial production of seed oil that involve the use of chemical dissolvent.

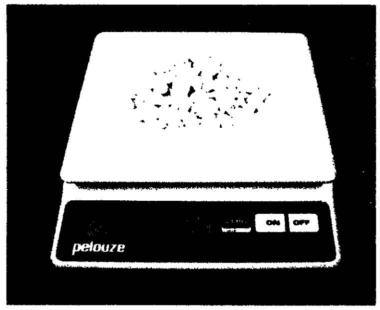
2.2 Materials

The experiments consisted of pressing the seeds using a hydraulic press (Carl Bielenberg's batch press – figure 3). I repeatedly applied two different pressure profiles illustrated in figure 4: one consisted of increasing the pressure in steps up to a final value (limited to 13.4MPa/1950psi by the physical limitations of the press); while the other profile consisted of increasing the pressure rapidly to the final pressure and holding it until no more oil flowed out. The pressure profile could be determined manually through the car-jack lever and the pressure-gauge indicator. The pressures I recorded in figure 4 are the effective pressures exerted on the seeds, not the one indicated by the pressure gauge; in fact, the area of the plate that affected the seeds was four times larger than the car-jack piston area. However, as confirmed by Carl Bielenberg, the pressure at which the oil begins to flow out of the cage is approximately 10.3MPa/1500psi (41.2MPa/6000psi on the indicator of the gauge).

The suggestions and advices of Carl Bielenberg have been a precious resource for this project. I partly modeled the oil extruder on the batch press Carl Bielenberg lent me (described here) and his most recent design of a lever/piston oil extruder he presented at the show case at MIT [11].

Other materials used for these experimentations are moringa seeds, an electronic balance and various utensils. I purchased germinable fresh seeds from Rodney Purdue's Moringa Farms in Sherman Oaks, California. These are soft-shelled seeds of a cream color. Their density is low compared to that of other type of seeds or fruits from which oil is normally extracted, such as peanuts. Therefore the oil extracted per unit volume is very low.

Figure 2: Moringa Seeds. 10 grams of moringa seeds.



The Bielenberg press is a batch press designed to conduct laboratory experiments. It consists of a car jack that pushes up a plate which, in turn, matches the bottom of a cage. A fixed piston fits tightly the inside the walls of the cage. The car jack pushes the plate and the cage up against the piston. Seeds contained inside the cage are trapped between the cage, plate and piston. Pressing the seeds, the oil flows out of the gaps of the cage and it is collected on the plate.

Figure 3: The Bielenberg Press. The bottom plate is lying on the floor in the left corner, the cage is hanging in the center, and the car jack is standing on the right corner. Note that the effective area that the seeds are pressed, the area of the inside circle of the cage, is approximately 4 times that of the car jack's effective area.

2.3 Procedures

In both types of experiments I tried to maintain a constant pressure where desired, within possible limits. In fact pressure is applied manually. The hopper was filled with a constant quantity of seeds (200g) and pressed in similar physical conditions. The experiments were conducted at room temperature. It seems reasonable to me not to consider temperature of the seeds as a relevant factor because the seeds are soft and easily pressed at such temperature. Experimentally, I established that a pressure of 10.3Mpa on the seeds is the minimum pressure necessary for oil to start flowing out of the cage. The maximum pressure that was possible to apply was 13.4Mpa due to two factors: the physical limits of the press and physical conditions of the seeds. In fact, a higher pressure caused the deformation of the welding of the plate, since four times as much pressure was applied to it. Carl Bielenberg suggested that an excessive pressure (higher than 13.4MPa would squeeze the seeds into a mash from which oil cannot be extracted efficiently, because oil is reabsorbed by the mash once extracted [8].

In the first set of experiments I set the starting pressure at 10.3MPa, and I applied increasing values of constant pressure in steps. For each step I kept the pressure constant until no more oil was extracted. The time intervals of each step were approximately 5 minutes.

In the second set of experiments, the goal I had was to apply the maximum pressure 13.4MPa fairly quickly from the beginning. At first I wasn't able to apply a pressure higher than 12.3MPa/1800psi. In fact, during compression the volume of the seeds quickly diminished, due to the low density of the seeds, balancing the pressure I applied to the value of 12.3MPa. At this stage no oil was extracted. Once the seeds were sufficiently compressed, such that the rate I would increase the pressure was higher than the rate the seeds' volume would diminish, I could increase the pressure to a range of 13MPa-13.4MPa/1900-1950psi. I maintained the seeds at this range of pressure until oil would not flow out anymore.

2.4 Results of Experiments

Taking into account the losses, similar quantities of oil were extracted in both sets of experiments. The second set of experiments, however, produced oil much faster partly because higher pressure pushed oil out of the seeds at a higher rate while yielding major differences in the results.

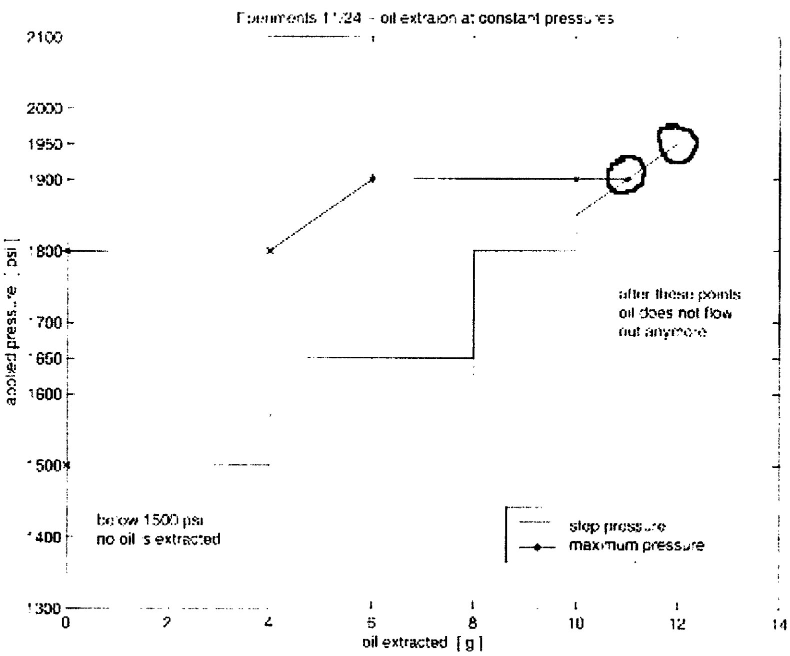


Figure 4:
Pressure (applied on seeds) [psi]
vs.
Oil Extracted [grams].

Experiments on 11/24/2003

Maximum quantity of oil is extracted are circled for both set of experiments

The batch press was designed to perform lab work. Inevitably, issues arose when employing a press for experiments for production. Those issues were very useful, though, to individualize key points in the design of a press. In fact, although car-jacks are a very convenient source of pressure because they are widely available at an inexpensive price, they require considerable human energy to apply the needed loading. Moreover, the use of the lever can strain the muscles of the back.

Losses were consistent compared to the little quantity of oil extracted; in fact, I had to limit batch quantity to 200g of seeds. Losses were mainly caused by the inability to collect all the oil extracted. This fact required that the cage be cleaned frequently so that the oil could flow easily out of the tiny gaps in a quantity sufficient to be weighed. Moreover, the surface tension between the oil and the metal caused the oil to form a sticky layer on the metal that reduced the amount of oil collected. Once the metal was coated with oil, in subsequent extractions the oil flowed over it and losses sharply decreased. Another major cause of loss was the deformation of the plate, on which it was not possible to apply pressure uniformly. The weld of the plate indicated in figure 4 deformed along with thin parts of the plate. I will try to find thicker material to remake the plate, in gratitude to Carl Bielenberg for his kindness in lending me his press. More errors were caused by random spills of oil and the imprecision in maintaining constant pressure.

A lot of human energy and strength were wasted in operating the press. For instance, to force the compressed cake out of the cage I had to kneel, consequently tiring the muscles of my back and arms rather than my leg muscles. In addition, while applying a high torque on the lever of the car jack I had to hold the top of press to prevent its falling on me and consequently I could not use my weight to step on the lever.

Higher amounts of debris are obtained in the second set of experiments; however, the debris is soft enough not to constitute a significant problem upon assumption that the cage is cleaned on a regular basis.

2.5 Conclusions and Discussion of Results

These experiments showed that, for a maximum pressure of 14.3MPa, similar quantities of oil are extracted independently of the applied pressure profile. This is contrary to what Carl Bielenberg experienced. This result does not place a limit in the design development stage. However, my major concern is that I extracted only small quantities of oil from the seeds, approximately 6% by weight (oil/seeds) compared to the 10-15% content I expected to obtain. It is not completely clear to me what the reasons of this are, but I hypothesize that among the factors there are the freshness of the seeds and the insufficient pressure applied.

2.6 Further Work

Further work could include the application of higher pressure to find the maximum pressure applicable before the seeds are mashed, and the investigation of how freshness and stage of maturity of the seeds influence the quantities of oil extracted.

Chapter 3

Design

3.1 Design Concepts

First I developed a preliminary set of ideas based only on the literature search I had previously done. This included the concepts used in extraction of other type of seeds. After I conducted the experiments on the seeds, I picked the concepts that seemed most convenient. It is ideal to design a human-powered press due to limited availability of electricity in Haiti. A pedaling system, as shown in figure 5, allows the use of powerful leg muscles while comfortably sitting and gives the possibility to perform more tasks with the hands, such as feeding the seeds into the press.

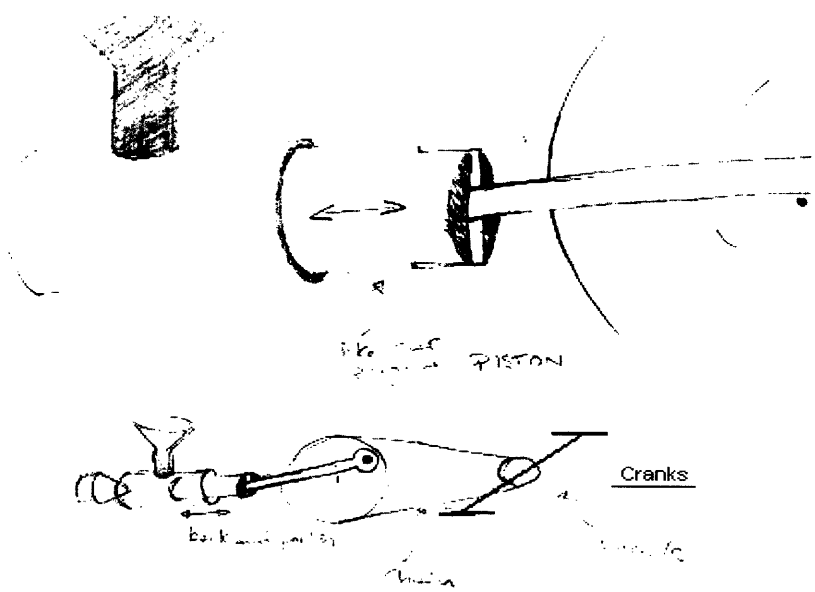


Figure 5: Pedaling System applied to Bielenberg lever press.
Pedals (indicated by "bicycle" in the picture) drive a transmission system that through a shaft drives the piston in and out the press.

According to Professor Dave Wilson, people are able to pedal to produce 100Watts at a rate of 60rpm for a reasonable amount of time. Therefore the torque produced would be equal to:

Torque [N-m] = 100 [watts] / (60 * (2*pi/60) [rad/sec])

Torque (bike) = 9.5[N-m].

Using a chain to transmit the torque, from a wheel to a wheel with radius three times as big, the Torque that would be applied to the press would equal Torque(press)=28.5[N-m], which is not sufficient for a pedal system to drive the Bielenberg press. However, Carl Bielenberg developed another press (figure 5 – using a lever system instead of a pedaling one) [11] in which a lever drives the compression of seeds. I personally tried it out, and I will estimate that I used 35N of my weight, the arm was 1.5m long, and the cage had a 5cm radius and was 10cm long. Therefore, this other machine applied the following pressure on the seeds:

Pressure [N/m^2] = Torque [N] / (volume displacement per rev) [m^3/rad]

Pressure = ((pi/3)*35[N]*1.5[m]) / (0.05^2[m^2]*pi*0.1[m]) = 70000 [N/m^2]

Converting to psi: 6894*70000 [N/m^2] = 10.2[psi]

The much smaller pressure applied in the lever press depends on the fact that a much smaller volume of seeds were compressed at a time in this press compared to the batch press. The Bielenberg lever press presses seeds in a continuous motion producing a similar quantity of oil to that produced by the batch press, while applying less human force but for a longer time, which is more suitable for a pedaling system. In fact, the

Torque needed to run such a press would be around 52.5[N-m], which is comparable to the Torque that a pedaling system can produce (28.5[N-m] as described above). Possible Modifications to adjust the powering system include the radii of the bicycle and press disks, the length of the cranks and the volume of seeds compressed.

3.2 Selection of Design Concepts

Based on the experiments and desired features I selected three designs that seemed to better satisfy the findings of the experiments and the elastic characteristic of the seeds. The fact that oil extracted is independent of how the pressure is applied determined that either a continuous or a batch system would be suitable. However, it is important to be able to apply and hold pressure to avoid energy losses and mashing the seeds. As mentioned above, mashing the seeds makes it harder to separate oil and seeds because the mash reabsorbs the oil and also because the mash could partially flow out of the cage with the oil. While introducing one more step in the process to recover the oil mixed in the mash could help the recovery, oil and more energy would be lost. [9] [10].

3.3 Development and Evaluation of Design Ideas

Carl Bielenberg provided me with vital information about design of appropriate technology for oil extraction. A constant and/or increasing pressure is desired. In view of that, I selected the internal-screw design (figure 9) as most suitable of the three designs I chose at first for this process. The softness of the moringa seeds compared to that of meat makes me think that a modified meat grinder can work well for the seeds. A meat grinder of small size allows the use of pedaling system, as just explained, while the shape of the screw could potentially influence the performance on the seeds. In fact, the piston system (figure 8) based on Carl Bielenberg's design could not properly apply pressure long enough to guarantee the efficacy of the extraction. Moreover, the flywheel design (not shown here) required a few minutes to reload.

Carl Bielenberg's cage design consists of metal bars set as a section of a cone that form 2mm gaps. One of the bases (*C*) of the cage has a diameter slightly bigger than the other one; the increase in area allows the cake to be pushed out of the cage rather than pressed out, reducing the waste of energy. As shown in figure6, on the same axis a cone points towards the inside of the cage. The cone can be moved axially towards or far from the cage. By adjusting the position of the cone, it is possible to adjust the pressure inside the cage [11].

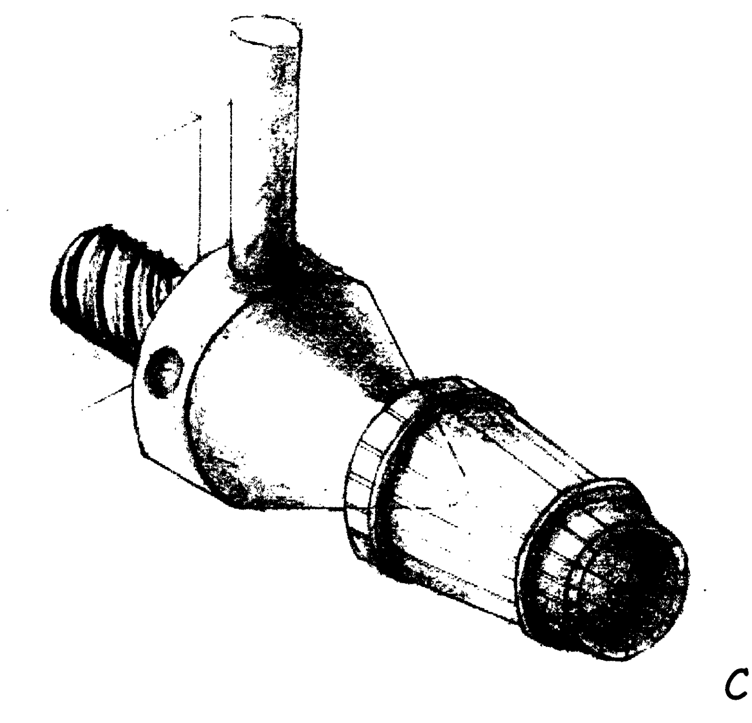


Figure 6: Design of Carl Bielenberg Cage. The cage is of conical shape, and the seeds "travel" from end "C" towards the tip of the cone. End "C" is smaller. The cone provides pressure inside the cage that is adjusted axially by rotating the cone (note the screw on its back).

However, I decided to modify the design of Carl Bielenberg cage because I was concerned about the ability to maintain a constant or increasing pressure to avoid the reabsorption of the oil caused by the elastic property of the moringa seeds. Carl Bielenberg himself pointed out that reabsorption of oil is most problematic in moringa seeds than any other type of seeds, such as peanuts, he has been working with.

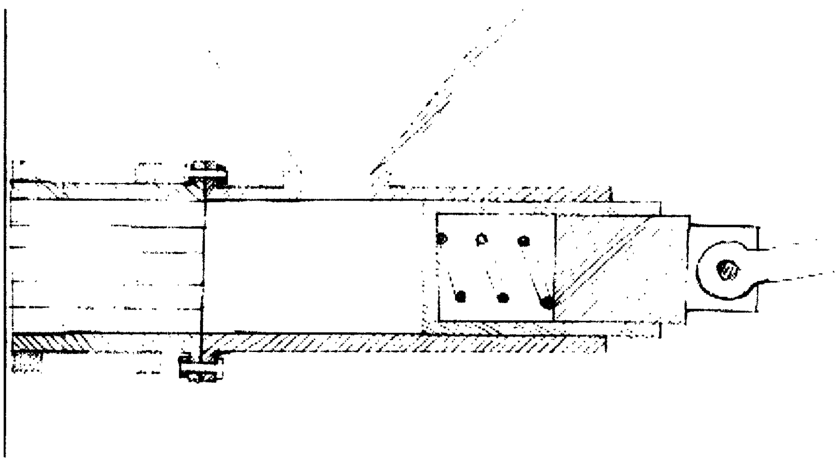


Figure 7: Preliminary Drawing of Spring-Piston Press. Inside the piston there is a spring that provides a constant force for longer time between cycles.

B

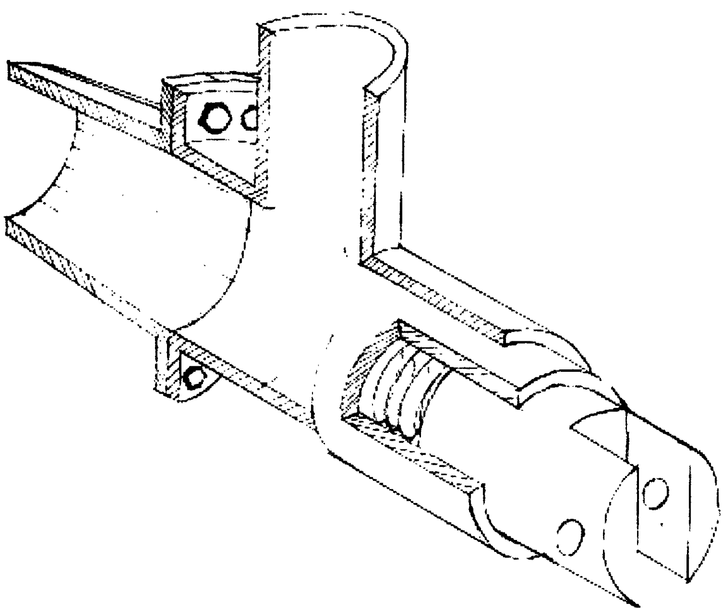


Figure 8: Improved Design of Spring-Piston. The piston is shown in position of maximum retraction.

As shown in figure 8 the cage I designed is a cone that becomes smaller as the seeds are pressed towards the open end 'B", to provide constant pressure to the seeds. I also realized that in my design (figure 9) the cake could potentially clog the cone, so in the internal screw design I elongated the screw to stir the cake so that t can better flow out. In particular, the screw tip does not fit the inside walls of the cage as the screw does inside the meat grinder.

3.4 Selection and Development of Final Design

In summary, I selected the internal-screw system for the following reasons: it can be designed as a continuous system, it provides a constant pressure reducing the problem of reabsorption, and it can be easily and cheaply produced by modifying meat grinders. There is to be noted that I replicated the screw from the model of a meat grinder and added a tip of conical shape. Therefore, the screw is designed for meat and might not work as well for moringa seeds. In a meat grinder, under the hopper the meat grinder spiral is more inclined to allow chunks of meat to be inserted; while at the other end the plane of the screw is almost perpendicular to the cutting disk to use more force to push the meat to pass through the holes of the disk. The portion of the spiral inside the cage is slightly smaller and does not fit the cage, because it's only purpose is to stir the seeds/cake to prevent them form clogging the cage. Ridges on the inside of the meat grinder create friction. It is important that the coefficients of friction between the inside walls of the meat grinder and the surface of the screw are different, so that the seeds move from the hopper to the open end of the cage.

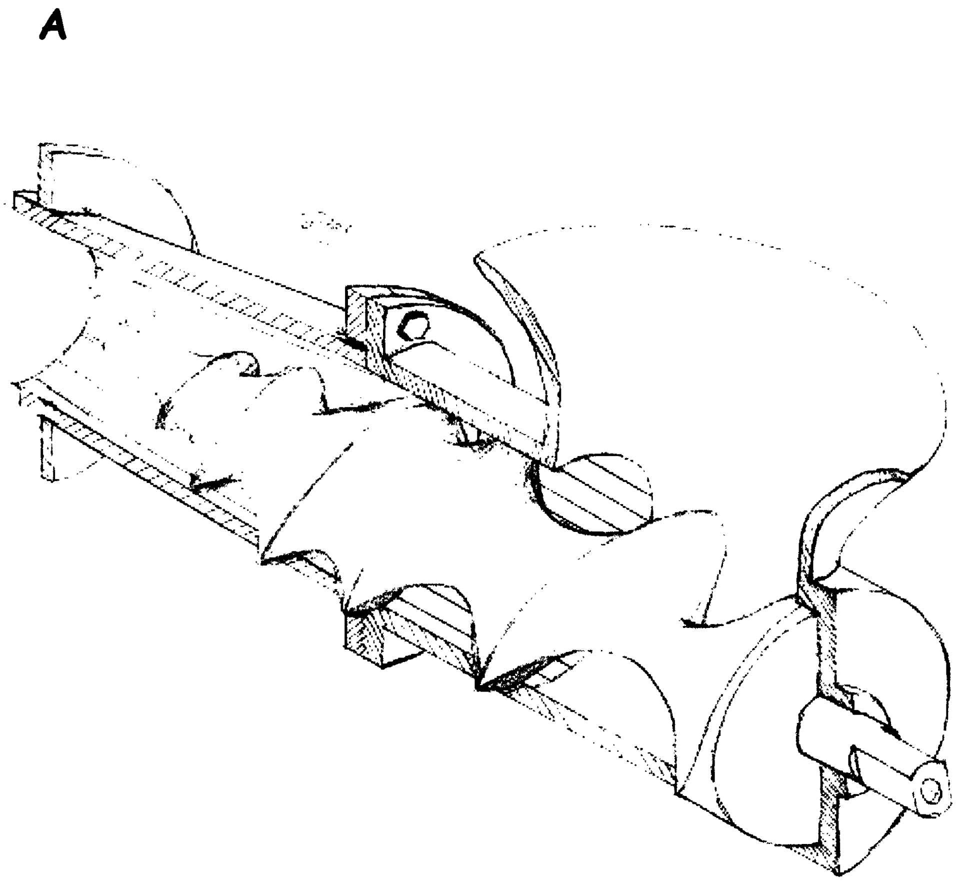


Figure 9: Internal-Screw Press.
A meat grinder has been modified by elongating and thinning the tip of the screw, and adding a conical cage at one end.
The ring at end "A" has the double function of providing support to the cage and to prevent the oil on top to run down the side of the cone and fall into the cake collector (not shown).

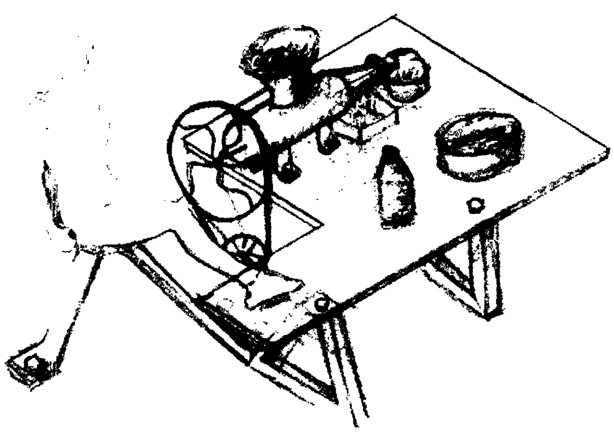


Figure 10: Setting of Press with Pedaling System.

Chapter 4

Discussion of Project

4.1 Conclusions and Recommendations

This study is a step towards adapting existing technology to extraction of oil specifically from moringa seeds. I showed that the pressure profile does not affect the efficiency of the extraction process; however, the pressure needed to extract oil with Carl Bielenberg batch press is very high to use a pedaling system to drive the press. Consequently a batch press is not ideal for village use, unless use alternative source of energy are available such as rivers in the case of Haiti. Furthermore, considering that the oil is employed mainly for cooking purposes, only a small quantity needs to be produced everyday. In fact, this project aimed at designing a product for a small village where electricity is not available. One advantage of the internal-screw press is that meat grinders are produced in different sizes [14].

While a cylindrical or conical cage can bear a lot pressure, its design can certainly be improved by exploring different geometries of the position and shape of the gaps.

In conclusion, the combination of many factors influences the efficiency of the process of oil extraction. The parameters of some of those factors can be easily adjusted, while others cannot. For a design of an oil extractor for a developing country it is necessary to compromise, especially because resources are limited. While optimal oil extraction requires a multi-step production to obtain a high performance and investments in expensive machinery, a small village only needs limited quantities of oil. Considering that the cake can be used as food for animals and babies and as fertilizer, the efficiency of the oil extraction can be traded with the fact that the seeds won't be wasted. At the same, time oil is needed to cook and to produce soap; sometimes the oil can even used as fuel.

In view of these facts, I recommend to focus future work on developing the cage design, investigate on the shape of the screw that yields better results for moringa seeds, and alternative energy systems to drive the press.

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